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EVALUATION STUDY OF DIRECT RECIRCULATION
ON A HIGH-RATE TRICKLING FILTER, NEWBERRY,
S. C.

Russell S. Smith, et al

Environmental Health Center
Cincinnati, Ohio

1952

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EVALUATION STUDY
OF
DIRECT RECIRCULATION
ON A
HIGH-RATE TRICKLING FILTER
NEWBERRY, S.C.

By

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Public Health Service
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1. Summary and Conclusions

A study was made at the Newberry, South Carolina, sewage treatment plant to evaluate the performance of a high-rate trickling filter recirculating the filter effluent to the filter influent and to obtain additional information on the suitability of this method of recirculation for high rate filtration of domestic sewage. A previous study had been made at Webster City, Iowa, to make a direct comparison of recirculation to the filter influent of filter effluent and settled plant effluent. (1)

The plant at Newberry was designed and constructed as a direct recirculation type high-rate trickling filter plant, and was being operated as such. Aside from the installation of flow measuring devices, only minor adjustments were required at the plant for this study. Observations were made under the conditions of normal plant operation.

Nine 24-hour and an equal number of 4-hour test runs were made during the two-week period covered by the study.

The volumetric ratios of recirculated filter effluent to primary clarifier effluent averaged 2.1:1 over the entire study period of the 24-hour tests, and the filter loadings, with recirculation included, averaged 10 million gallons per acre per day and 1.4 pounds of 5-day B.O.D. per cubic yard of filter material per day. For the 4-hour tests, the average recirculation ratio was 1.0 and the filter loadings with recirculation averaged 10.3 m.g.a.d. and 2.2 pounds B.O.D. per cubic yard of filter media per day.

Starting with a strong sewage, excellent average over-all plant efficiencies (based on BOD removals) of 91% for the 24 hr. and 88% for the 4 hr.

tests were obtained. These efficiencies are higher than would be anticipated from a high rate filter plant recirculating final effluent at a 2:1 ratio and treating a settled sewage as strong as that at Newberry.

Although the applied filter loading in pounds of biochemical oxygen demand per cubic yard of media per 24 hours was about half the maximum allowed for single stage high rate filters by the states represented on the Upper Mississippi and Great Lakes Boards of Public Health Engineers,⁽²⁾ the biochemical oxygen demand of the effluent approached that which might be expected from a standard rate trickling filter plant treating a sewage of this strength. The nitrite-nitrate nitrogen content was considerably lower than would be anticipated in the effluent from a standard rate trickling filter plant.

With the filter loadings used, no evidence of ponding was observed during the study period, nor had there been any difficulty from ponding during the two years that the plant had been in operation.

2. Introduction

A. Statement of Problem

The effects of direct recirculation, or the recirculation of filter effluent to the filter influent, on the operation of high-rate trickling filters were investigated by the Public Health Service at Webster City, Iowa, in 1950.⁽¹⁾

A particular advantage of direct recirculation is the reduced capital cost of a treatment plant because neither primary nor secondary settling tanks need be designed to handle flow volumes in excess of the raw sewage. Claims have been made that the return of active biological agents in this manner increases the efficiency of the filter.

Previous to the Webster City study, undertaken at the request of the Great Lakes and Upper Mississippi River Boards of State Public Health Engineers, very little data had been available to judge the suitability of the process for particular installations and the efficiency of this method of recirculation in comparison with other more conventional methods.

It was found at Webster City that, for the conditions prevailing at that treatment plant, the efficiency and general performance of a direct recirculation type high-rate trickling filter were at least equal to the corresponding qualities of a high-rate filter with final effluent recirculation.

The ultimate objective of the direct recirculation investigations is to provide essential information upon which to base the review of plans of proposed plants using this type of secondary recirculation. Following the Webster City study, evaluation studies seemed advisable at one or more

existing direct recirculation type plants under organic loadings equal to, or slightly greater than, those used at Webster City to obtain further information on treatment efficiencies and the suitability of this process for treatment of municipal wastes.

Features that entered into the selection of a test plant were: (1) recirculation ratio of at least one volume of recirculated flow to one volume of raw sewage flow; (2) a filter dosing rate of 15 m.g.a.d.; (3) adequate provision for measurement of raw sewage and recirculation flows; and (4) a separate sewer system.

The treatment plant at Newberry, South Carolina, fulfilled most of the requirements and was selected as a test site. Moreover, the proximity of the community of Augusta, Georgia, where a field staff of the Environmental Health Center was located, made it convenient for the Public Health Service to conduct the study at Newberry.

Field work on the study was commenced on November 16 and was completed on November 28, 1951.

B. Organization

The study was made by the Environmental Health Center of the Public Health Service with the cooperation of the South Carolina State Board of Health, the South Carolina State Water Pollution Control Authority, and the City of Newberry.

The City, through its manager, Mr. E.L. Blackwell, provided the site and extended its whole-hearted cooperation to the project. Mr. Hugh H. Connelly, superintendent of the plant, was most helpful in making the necessary plant adjustments.

The State Health Department and the State Water Pollution Control

Authority showed great interest in the project and fully collaborated in the entire study. The Water Pollution Control Authority provided two sample collectors to make possible a 24-hour sampling program.

All other personnel for the project and the laboratory facilities were provided by the Environmental Health Center, utilizing the field staff and facilities at Augusta, Georgia. The Environmental Health Center also furnished the engineering supervision for the entire project and prepared and reproduced the project report.

Field personnel assigned to the project and their sponsoring organizations were as follows:

PUBLIC HEALTH SERVICE

Public Health Engineer Russell S. Smith
Sanitary Engineer Donald D. Gold
Assistant Sanitary Engineer Albert L. Platz
Chemist Jesse M. Cohen
Chemist Carl Shadix

SOUTH CAROLINA STATE WATER POLLUTION CONTROL AUTHORITY

Sample Collector John Smith
Sample Collector William McIntire

3. Plant Description and Engineering Data

A. General Description

The population of Newberry, South Carolina, is 7546 according to the preliminary figures from the 1950 census. The city is the hub of a farming area. The storm and sanitary sewer systems are separate. The flows in the sanitary sewers were noted to increase rapidly at time of storm, however, indicating that storm water enters the sanitary sewers at some undetermined points.

Three cotton mills are the major manufacturing plants in the community. Two of the mills make gauze products and the third produces sheetings. Wastes from these mills are tributary to the city's sewage treatment plant. The sewage treatment plant also serves two milk receiving plants, a laundry, a poultry packing plant, and a 100-bed hospital. The sewage from the community is stronger than that which would be expected from a small manufacturing town.

The plant is located a short distance from town and the effluent is discharged into a sub-tributary of the Saluda River. The component parts of the sewage treatment plant are: (1) two comminutors with an inclined, manually cleaned by-pass bar-screen; (2) a circular primary clarifier with sludge removal and skimming devices; (3) a circular high-rate trickling filter; (4) a circular secondary clarifier identical to the primary, except with no skimming device; (5) a circular, heated, floating-cover sludge digester; and (6) two open sludge drying beds with under-drainage discharging to the receiving stream. By-pass provision for the raw sewage is made at a point before the comminutors. The secondary clarifier can be by-passed by the manipulation of valves in the diversion box following the filter.

The plant's high-rate trickling filter was designed and constructed as a direct recirculation type, and is being operated as such. The design population is 12,000. The plant is relatively new, having been in operation about two years.

The sewage entering the plant passes through an open weir-box with V-notch weir and head gage recording the flow rate in thousands of gallons per day and then through the comminutors to the primary clarifier.

The effluent from the primary clarifier discharges into the head-box of the filter, as does the recirculated filter effluent. The pumps recirculating the filter effluent are controlled by individual float switches in this head-box. These float switches are so arranged that normally one pump will operate continuously and the other intermittently as necessary to maintain a reasonably constant flow through the filter.

The maximum recirculation pump capacity is 800 gpm.

The recirculated portion of the filter effluent is taken from the diversion box following the filter. The remainder of the filter effluent flows by gravity to the final clarifier, from which the plant effluent passes to the receiving stream.

Sludge from both clarifiers is pumped to the digester. The sludge is heated by circulation through an external heat exchanger with heat provided by a gas fired hot-water heater built into the heat exchanger. The heat exchanger was not in operation during the study period. The digester supernatant is returned to the comminutor chamber and the digested sludge is drawn off to the drying beds.

B. Plant Units

Raw sewage flow measuring devices

90-degree V-notch weir on the plant influent
B. I. F. Chronoflow Transmitter and Recorder, to convert the head readings on the weir to flow measurements in thousands of gallons per day

Screen

Two Chicago Pump Company 10-inch Comminutors
Bar screen (by-pass), manually cleaned

Primary clarifier

Circular clarifier, 36' in diameter with external launder,
side water depth 8'-2", floor slope 1:12
Surface area, 1017 square ft.

Primary clarifier (cont'd)

Volume, 62,100 gal.

Weir length, 113 feet

Infilco sludge collecting and skimming mechanisms

Filter head box

Ten feet square by two feet deep

Filter

Infilco Accello filter, 30' in diameter with 4'-6" depth of media

Filter area, 5030 square ft. or 0.115 acre

Media volume, 835 cubic yd.

Single two-armed distributor, orifice and splash plate, reaction driven unit

Recirculation pumps

Two Fairbanks Morse 4", No. 5432, each rated at 400 g.p.m. at 10 ft. head

Secondary clarifier

Identical with primary clarifier, except no skimming device provided

Sludge pumps

Two Domestic Engine and Pump Company, single cylinder piston pumps with adjustable stroke

Sludge digester

55' diameter digester with floating cover, external heat exchanger with built in gas-fired hot-water heater

Sludge drying bed

Two open beds, each 60' by 100'

Area, 6000 square ft. per bed or 1 square foot per capita (design basis)

Tile under-drains

CLARIFIER CHARACTERISTICS
As Observed During Study Period
(Daily Average Results)

<u>Characteristics</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Average</u>
Detention period hours	4.7	3.5	3.9
Surface settling rate gal./sq.ft./day	420	320	370
Weir over-flow rate gal./lineal ft./day	3,750	2,880	3,320

4. Hydrometric and Sampling Data

A. Hydrometric Data

The only flow measuring device provided at the plant was a weir-box with a 90-degree V-notch weir, located at the inlet to the plant to measure the quantity of in-coming raw sewage. A float in the stilling-well adjacent to the weir-box operated the chronoflow transmitter connected to an indicating and recording mechanism in the control building. The stilling-well and the pipe connecting it to the weir-box were continuously flushed with a small stream of clean water.

A hook gage was installed in the weir-box and the chronoflow recorder was checked on several occasions. The agreement between the two methods of flow measurements was generally within plus or minus five percent. Since the two gauges were found to indicate substantially the same flow,

the direct flow readings of the chronoflow recorder were used in this study for the sake of convenience.

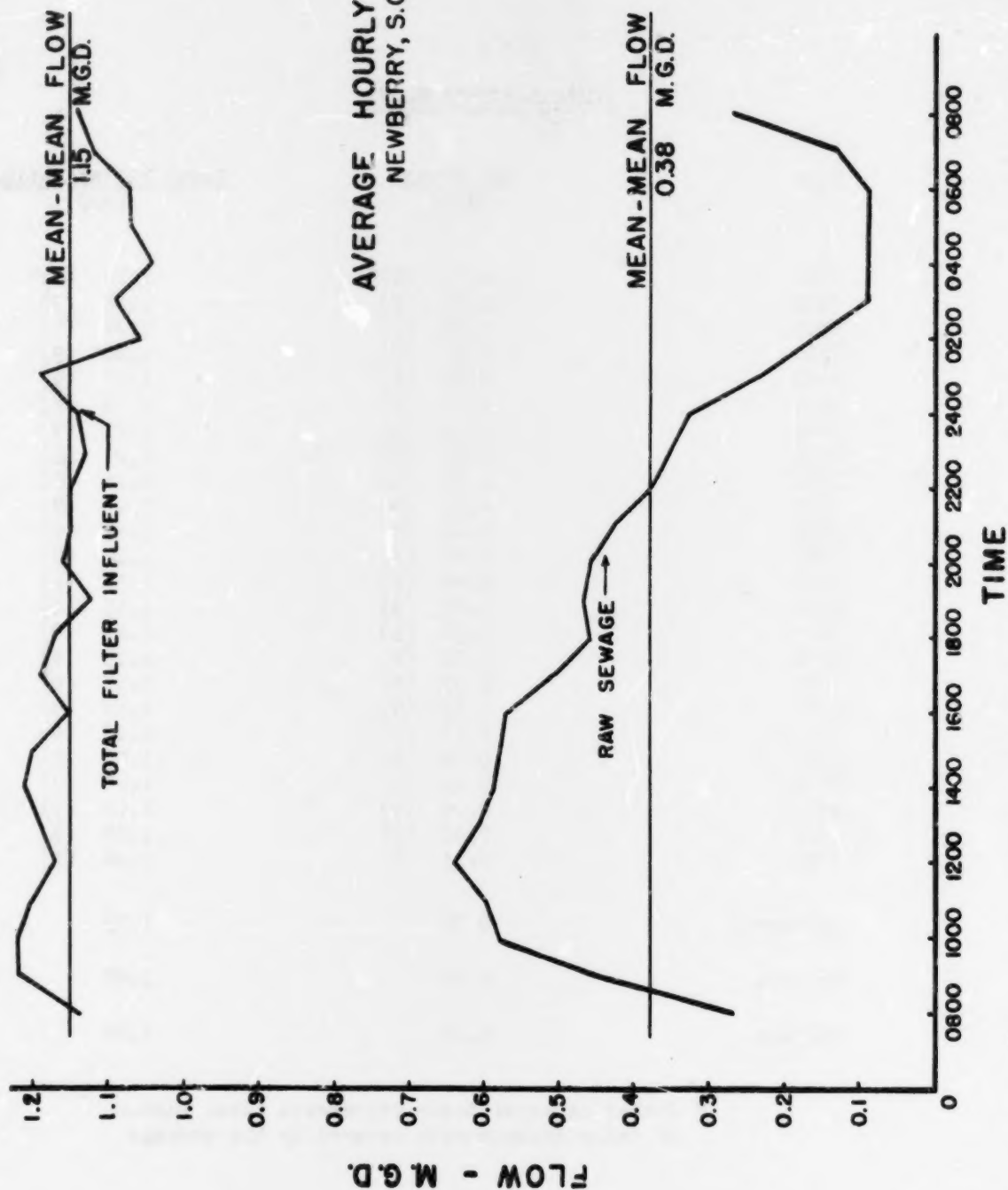
Direct measurements of recirculation flow would have been highly desirable in this study, but no provision had been made for such measurements in the construction of the plant. No straight section of the recirculation pump discharge piping was available for the installation of an orifice. The volume of the recirculation flow was therefore determined indirectly, by building a suppressed weir with a crest length of 24 inches at the outlet of the drain channel of the filter. The crest of the weir was 0.85 feet above the bottom of the channel and the weir was so constructed that the nappe was well aerated. Head readings for the weir discharge determinations were made with a hook gage and varied from 0.345 to 0.442 feet. The calculated flows at this point indicated the total flow through the filter, or the primary clarifier effluent plus the recirculation flow. The recirculated flow at any time of reading was taken to be the difference between the total filter flow and the raw sewage flow at that particular time.

The average hourly rates of flow of raw sewage and total filter influent, during the period of this study are listed in Table 1. The same data are shown graphically on Figure 1.

Table 1
AVERAGE HOURLY FLOWS

<u>Time</u>	<u>Raw Sewage</u> (MGD)	<u>Total Filter Influent</u> (MGD)
0800	0.27 (9)*	1.14 (8)*
0900	0.45 (9)	1.22 (9)
1000	0.58 (9)	1.22 (7)
1100	0.60 (9)	1.20 (9)
1200	0.64 (9)	1.17 (9)
1300	0.61 (9)	1.19 (9)
1400	0.59 (9)	1.21 (9)
1500	0.58 (9)	1.20 (8)
1600	0.57 (9)	1.15 (8)
1700	0.51 (9)	1.19 (8)
1800	0.46 (9)	1.17 (9)
1900	0.47 (9)	1.12 (9)
2000	0.46 (9)	1.16 (9)
2100	0.43 (9)	1.15 (9)
2200	0.38 (9)	1.15 (9)
2300	0.35 (9)	1.13 (9)
2400	0.33 (9)	1.14 (9)
0100	0.23 (9)	1.19 (9)
0200	0.16 (9)	1.06 (9)
0300	0.09 (9)	1.09 (9)
0400	0.09 (9)	1.07 (9)
0500	0.09 (9)	1.07 (9)
0600	0.09 (9)	1.07 (9)
0700	0.13 (9)	1.12 (7)
Average	0.38	1.15
Maximum	0.64	1.22
Minimum	0.09	1.04

* Number in parenthesis represents total number of daily measurements covered by the average



AVERAGE HOURLY FLOWS
NEWBERRY, S.C.

Flow rate data for the 24-hour periods and the 4-hour maximum flow periods are summarized on Table 2. The flows through the primary and secondary clarifiers were taken to be the same as the raw sewage flow.

Table 2

SUMMARIZED HYDROMETRIC DATA - DAILY AVERAGES

<u>Value</u>	<u>Flow Rates - MGD</u>		<u>Filter Influent</u>	<u>Recirculation Ratio</u>	<u>Filter Dosing Rate-MGD</u>	
	<u>Raw Sewage</u>	<u>Recirculation</u>			<u>Settled Sewage</u>	<u>Total Flow</u>
24-hour Tests						
Avg.	0.38	0.77	1.15	2.1	3.3	10.0
Maximum	0.43	0.88	1.21	2.8	3.7	10.5
Minimum	0.32	0.72	1.10	1.7	2.8	9.6
4-hour Tests						
Avg.	0.60	0.59	1.19	1.0	5.2	10.3
Maximum	0.66	0.81	1.31	1.6	5.7	11.4
Minimum	0.51	0.52	1.11	0.8	4.4	9.7

No filter distribution tests were made at Newberry. The distributor column of the filter was operating without any leakages, and the sewage distribution over the entire filter area appeared to be good. The growth, green in color, on the surface of the filter media appeared even. There were no signs of ponding during the period of the study.

B. Sampling Points

Samples were collected at five points through the plant where distinct

changes in the characteristics of the sewage were anticipated to occur. Each sampling point was assigned a station number for recording purposes, in the following order:

<u>Sample Point</u>	<u>Station Number</u>
Raw sewage	1
Primary clarifier effluent	2
Filter influent	3
Filter effluent	4
Final clarifier effluent	5

The raw sewage samples were taken from the weir-box above the weir. The effluent samples of both clarifiers were taken at the outlet points in the launders. The filter influent samples were taken from the outer orifice of a distributor arm, while the filter effluent samples were taken at the outlet end of the drain channel of the filter. All sampling points were readily accessible, and no difficulties were encountered in sample collections.

G. Collection, Compositing and Transportation of Samples

The routine samples were collected and composited for 24-hour and 4-hour periods. The 4-hour composite samples were taken to observe the effects of the daily heavy flow periods on plant operations. All composite samples were kept under refrigeration at about 5°C. from the time of collection until they were delivered to the Augusta, Georgia, laboratory.

The 24-hour periods started at 8:00 A.M. on the sample date and terminated at 7:30 A.M. on the following day. Samples were taken at hourly intervals at all points except point number one, where the raw sewage was sampled

every half-hour. The individual portions for the composite were proportioned to the nearest five milliliters according to the flow at the time of the sampling. The proportioning was based on the raw sewage flow rates for the raw sewage and clarifier effluent composites and on the total filter influent flow rates for the filter influent and effluent composites.

The sample collection periods on the 4-hour runs were staggered to allow for the average detention periods of the various plant units. The intervals of sampling and the basis of proportioning for the composites were the same for the 4-hour runs as those for the 24-hour tests.

For the 4-hour composite samples, the raw sewage initially was sampled from 9:00 A.M. to 12:30 P.M. Through the rest of the plant, the detention time, based on estimated average raw sewage flow between 9:00 and 12:30, was determined for each plant unit, and the starting times of the sampling period were staggered accordingly. As initially set, the sampling periods of the primary clarifier effluent, filter influent, and filter effluent had a lag of two hours and the sampling period of the final clarifier effluent had a lag of four hours from the raw sewage period. After three days of sampling, the starting time was changed to 10:30 A.M., as the heaviest continuous 4-hour flow period seemed to occur subsequent to that time. The lag periods for the staggered operations were also increased to two and a half hours for the primary clarifier effluent, filter influent and filter effluent, and to five hours for the final clarifier effluent.

Special grab samples were collected six times daily from all five stations used in the routine sampling.

The composite samples were transported at the end of the sampling

period to Augusta, Georgia, for analysis. The time of travel between Newberry and Augusta, a distance of 60 miles, averaged about one hour and ten minutes.

5. Analytical Procedures

Biochemical oxygen demand, suspended solids, and nitrogen determinations were made on the composite samples at the Augusta laboratory.

Dissolved oxygen and colorimetric hydrogen ion concentration determinations were made on the grab samples by the sample collectors, following instructions given by the chemists. Temperature readings were also taken of the grab samples.

In general, analyses were made in accordance with procedures given in the "Standard Methods for Examination of Water and Sewage, Ninth Edition (1946)." The sodium azide modification of the Winkler Method was used for all determinations of dissolved oxygen.

6. Analytical Results

Nine 24-hour composite samples and the same number of 4-hour composite samples were collected and analyzed for each sampling point during this study.

A. Biochemical Oxygen Demand Determinations

The average, maximum, and minimum biochemical oxygen demand values for each sampling point are summarized in Table 3. The results of the B.O.D. determinations are expressed as parts per million of 5-day demand at 20 degrees Centigrade.

The B.O.D. values of the raw sewage were higher than is usual for the sewage of communities of the size of Newberry.

Table 3

5-Day B.O.D. (p.p.m.)

<u>Value</u>	<u>Raw Sewage</u>	<u>Primary Clarifier Effluent</u>	<u>Filter Influent</u>	<u>Filter Effluent</u>	<u>Final Clarifier Effluent</u>
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24-hour Composites

Average	391	254	126	85	37
Maximum	453	307	181	150	77
Minimum	300	212	88	32	24

4-hour Composites

Average	448	281	185	106	55
Maximum	537	347	250	242	145
Minimum	384	230	124	56	26

B. Suspended Solids Determinations

Exceedingly high percentages of volatile material in the suspended solids were noted throughout the study. The percentages were generally greater than 90 per cent, for both the 24-hour and 4-hour composites. The wastes discharged from the cotton mills probably contributed materially to this highly volatile nature of the suspended solids.

A summary of the results of the suspended solids determinations is shown in Table 4.

Table 4

Suspended Solids (p.p.m.)

	<u>Raw Sewage</u>		<u>Primary Clarifier Effluent</u>		<u>Filter Influent</u>		<u>Filter Effluent</u>		<u>Final Clarifier Effluent</u>	
	<u>Total</u>	<u>Vola</u>	<u>Total</u>	<u>Vola</u>	<u>Total</u>	<u>Vola</u>	<u>Total</u>	<u>Vola</u>	<u>Total</u>	<u>Vola</u>
<u>24-hour Composites</u>										
Average	294	272	104	100	90	85	91	82	32	30
Maximum	348	312	146	128	117	111	141	123	55	51
Minimum	244	244	70	66	58	58	46	44	20	17
<u>4-hour Composites</u>										
Average	404	367	130	123	125	120	97	87	35	34
Maximum	696	628	152	148	149	142	149	130	46	43
Minimum	324	300	110	108	81	80	44	44	24	23

C. Nitrogen Determinations

The results of both the 24-hour and 4-hour composite samples show that the plant was reducing the organic nitrogen content of the sewage by about 70 percent and that nitrification was being obtained. The nitrate content of the effluent was higher than would generally be expected for high-rate filter treatment with the loading and sewage strength found at Newberry.

The nitrogen results are summarized in Table 5.

D. Grab Sample Determinations

The results indicate that the sewage arriving at the plant was generally fresh with an appreciable dissolved oxygen content, most of which was consumed during the passage of the sewage through the primary clarifier. There was a pronounced recovery of dissolved oxygen through the secondary units of the plant.

No abnormality was found in the pH of the sewage entering the plant, nor were any unusual variations found in the hydrogen-ion concentrations of the waste in the various units of the plant.

A summary of the results of the determinations made on the grab samples is given in Table 6.

Table 5

Nitrogen Results (p.p.m.)

Raw Sewage				Primary Clarifier Effluent				Filter Influent			
Organic Ammonia Nitrite Nitrate		Organic Ammonia Nitrite Nitrate		Organic Ammonia Nitrite Nitrate		Organic Ammonia Nitrite Nitrate		Organic Ammonia Nitrite Nitrate		Organic Ammonia Nitrite Nitrate	
N	N	N	N	N	N	N	N	N	N	N	N
24-hour Composites											
Average	19.2	27.0	0.01	0.78	11.8	29.0	0.01	0.76	10.7	26.0	0.06
Maximum	22.9	32.0	0.05	1.80	14.5	34.0	0.04	2.00	16.1	30.0	0.15
Minimum	13.6	23.0	0	0.20	6.1	24.0	0	0.20	1.3	21.0	0.01
4-hour Composites											
Average	24.3	34.0	0.01	0.70	15.6	33.0	0.01	0.75	15.0	31.0	0.01
Maximum	28.1	44.0	0.03	1.20	19.7	42.0	0.03	1.60	20.4	37.0	0.04
Minimum	19.3	28.0	0	0.16	5.5	30.0	0	0.20	10.9	22.0	0
Filter Effluent											
Organic Ammonia Nitrite Nitrate		Organic Ammonia Nitrite Nitrate		Organic Ammonia Nitrite Nitrate		Organic Ammonia Nitrite Nitrate		Organic Ammonia Nitrite Nitrate		Organic Ammonia Nitrite Nitrate	
N	N	N	N	N	N	N	N	N	N	N	N
24-hour Composites											
Average	8.5	26.0	0.11	1.36	0.11	6.2	27.0	0.11	1.38	0.11	1.38
Maximum	12.2	30.0	0.16	2.10	0.16	9.3	32.0	0.15	2.80	0.15	2.80
Minimum	4.7	19.0	0.06	0.90	0.06	3.9	22.0	0.05	0.80	0.05	0.80
4-hour Composites											
Average	12.8	31.0	0.09	1.14	0.09	7.1	30.0	0.10	1.20	0.10	1.20
Maximum	21.1	36.0	0.13	1.40	0.13	12.5	34.0	0.14	1.70	0.14	1.70
Minimum	4.1	26.0	0.03	0.80	0.03	4.3	25.0	0.04	0.60	0.04	0.60

Table 6
Grab Sample Determinations

	Dissolved Oxygen-p.p.m.					Temperature - °F.				
	Raw Sew.	Prim. Clar. Effl.	Filt. Infl.	Filt. Effl.	Final Clar. Effl.	Raw Sew.	Prim. Clar. Effl.	Filt. Infl.	Filt. Effl.	Final Clar. Effl.
Avg.	1.2	0.4	3.1	3.6	2.8	62	62	60	60	60
Max.	5.3	1.2	6.5	6.9	6.2	69	69	70	70	70
Min.	0	0	1.0	1.3	0.8	58	59	55	53	55

	pH				
	Raw Sew.	Prim. Clar. Effl.	Filt. Infl.	Filt. Effl.	Final Clar. Effl.
Maximum	7.6	7.3	7.3	7.6	7.6
Minimum	6.6	6.3	6.6	6.8	6.7

7. Loadings and Efficiencies

The loadings, removals and efficiencies were calculated from formulas that were developed from the flow diagram. The flow diagram and a list of formulas used will be found in the appendix to this report. A summary of loadings, removals and efficiencies for various parts of the plant is given in Table 7.

Table 7
Loadings, Removals and Efficiencies

Value	Prim. Clarifier Efficiency-%		Filter Loading			Secondary Process BOD Removal		Secondary Process Removal-Percent of			Total Plant Efficiency-%	
	B.O.D.	Susp. Solids	Settled Flow-MGAD	Sewage BOD-lb/cu.yd./day	Filter Flow-MGAD	Influent BOD-lb./cu.yd./day	lbs./cu.yd./day	Raw Sew. BOD	Pri. Effl. BOD		BCD	Susp. Solids
24-hour Tests												
Average	35	65	3.3	0.97	10.0	1.44	0.83	56	86		91	39
Maximum	43	71	3.7	1.23	10.5	2.06	1.02	66	89		94	93
Minimum	25	48	2.8	0.81	9.6	1.00	0.69	48	75		82	81
4-hour Tests												
Average	37	66	5.2	1.69	10.3	2.21	1.36	51	81		88	91
Maximum	44	82	5.7	2.22	11.4	3.03	1.78	60	89		93	93
Minimum	29	60	4.4	1.36	9.7	1.49	1.11	38	58		73	89

The efficiency of the primary clarifier, based on removal of B.O.D., was good, the percentage of removal averaging 35 for the 24-hour tests and 37 for the 4-hour tests. The efficiency, based on suspended solids removal, averaged 65 per cent for the 24-hour and 66 per cent for the 4-hour runs.

The over-all plant efficiency in B.O.D. removal averaged 91 per cent for the 24-hour tests. The 4-hour tests, which were made at the time of maximum flow and sewage strength, showed a slightly lower over-all efficiency. Other studies of high rate filters⁽³⁾ indicate that single stage high rate filter plants may be expected to show over-all B.O.D. reductions varying from 75 to 85 per cent.

In this study, the filter loadings, including the recirculated flow, averaged 10 m.g.a.d. and 1.44 pounds of B.O.D. per cubic yard of stone per day, which are within the lower half of the range allowed for high rate trickling filters. "Standards for Sewage Works"⁽²⁾ states that high rate filters will be considered where a settled effluent with a 5-day B.O.D. of 30 p.p.m. or more is acceptable, but for such filters used with conventional primary settling tanks, the recirculation system shall provide sufficient dilution to the settled sewage so that the B.O.D. of the influent to the filter shall not exceed three times the B.O.D. of the required settled effluent. At Newberry, the B.O.D. of the filter influent averaged 126 p.p.m. and that of the final effluent averaged 37 p.p.m., a ratio of 3.6 to 1.

The relationship between the pounds of settled raw sewage B.O.D. applied to the secondary process (not including the load from recirculation) and the pounds of B.O.D. removed, each per cubic yard of filter media per day, are plotted in Figure 2 for the 24-hour tests and in Figure 3 for the 4-hour tests. The line of best fit for the recorded data was determined

in each case by the method of least squares.

The results from the tests made on November 27 (shown as Point Z in the figures) appeared to be abnormal and were not used in determining the lines of best fit. Exclusion of these data is justified due to the fact that the points in question deviate from the computed curves by more than the 95 per cent confidence limits for the lines. The reason for the abnormality has not been determined. The correlation of the remaining data used for the straight line plots was very high. The equations of the two lines and their respective coefficients of correlation are as follows:

<u>CURVE</u>	<u>EQUATION</u>	<u>COEFFICIENT OF CORRELATION</u>
24-hour Tests	$Y = 0.91 X - 0.031$	0.99
4-hour Tests	$Y = 0.93 X - 0.15$	0.94

where X = Settled Sewage B.O.D. applied in pounds per cubic yard of filter stone per day.

Y = B.O.D. removed by Secondary Process in pounds per cubic yards of filter stone per day.

It should be understood that these curves are applicable only within the range of data obtained during this study.

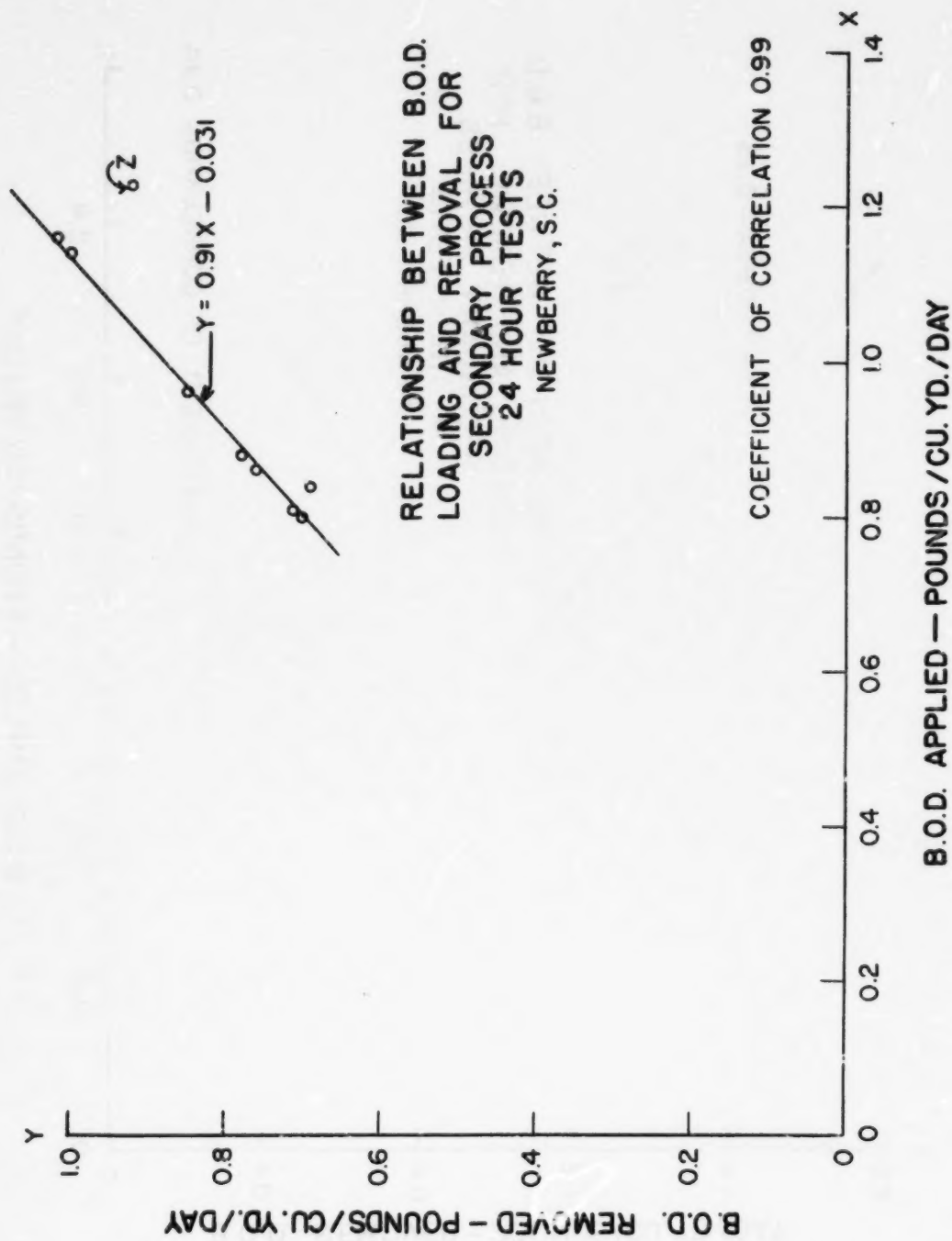
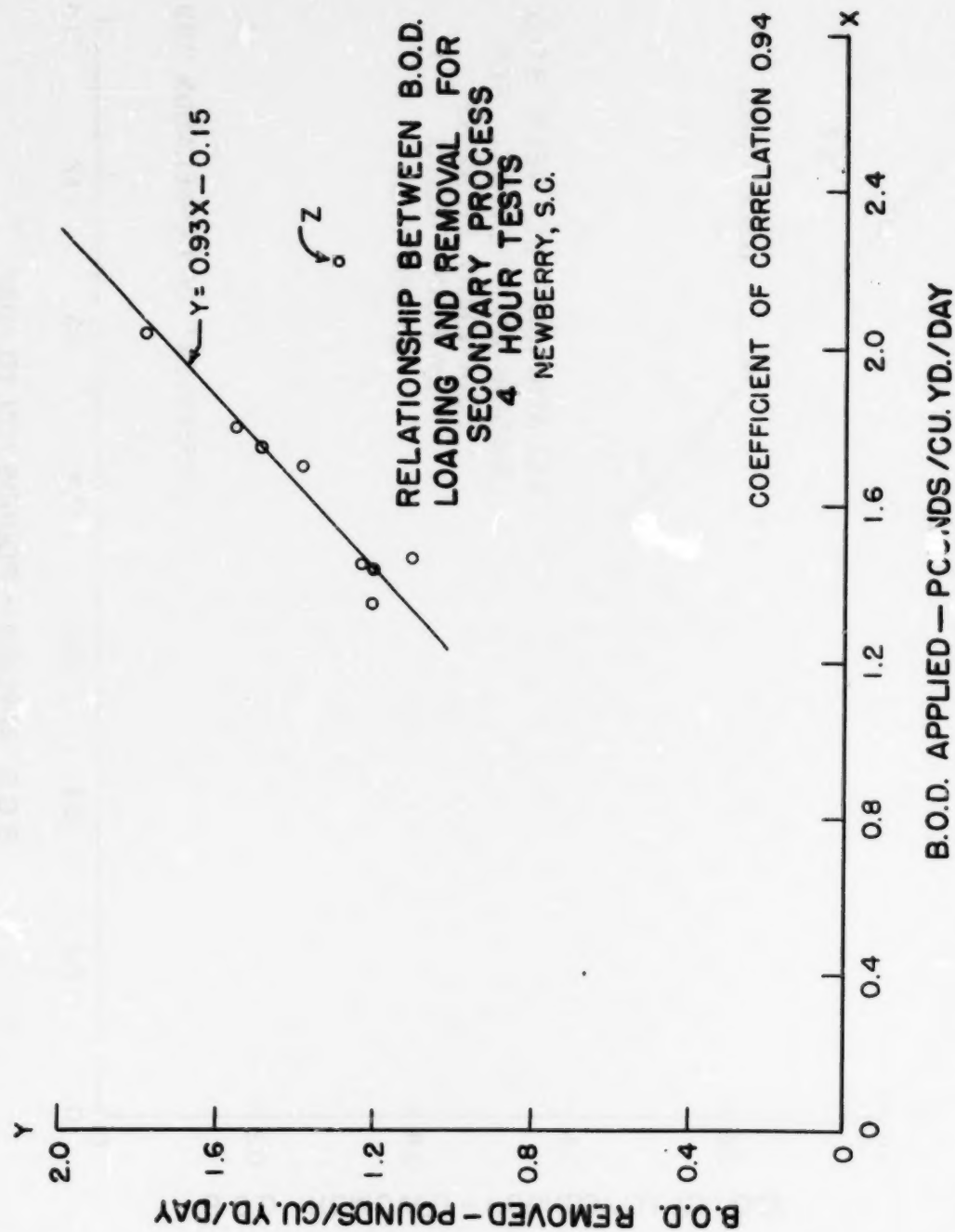


FIG. 2



BIBLIOGRAPHY

- (1) "Direct Recirculation for High Rate Trickling Filters."
Public Health Service, Environmental Health Center,
Cincinnati, Ohio, 1951
- (2) "Standards for Sewage Works." Upper Mississippi River
Board of Public Health Engineers and Great Lakes Board
of Public Health Engineers, May, 1952
- (3) Walton, Graham. "High Daily Rate Trickling Filter."
Published under direction of the Board of State Health
Commissioners, Upper Mississippi River Basin
Sanitation Agreement

APPENDIX

FLOW DIAGRAM

and

FORMULAS

Flow measurements were made and samples were collected as listed below. The locations of these flow measuring devices and sample points are shown on the flow diagram appearing on the following page and are as follows:

Flow Measurements

- a (V-notch weir)
- d (Suppressed weir)

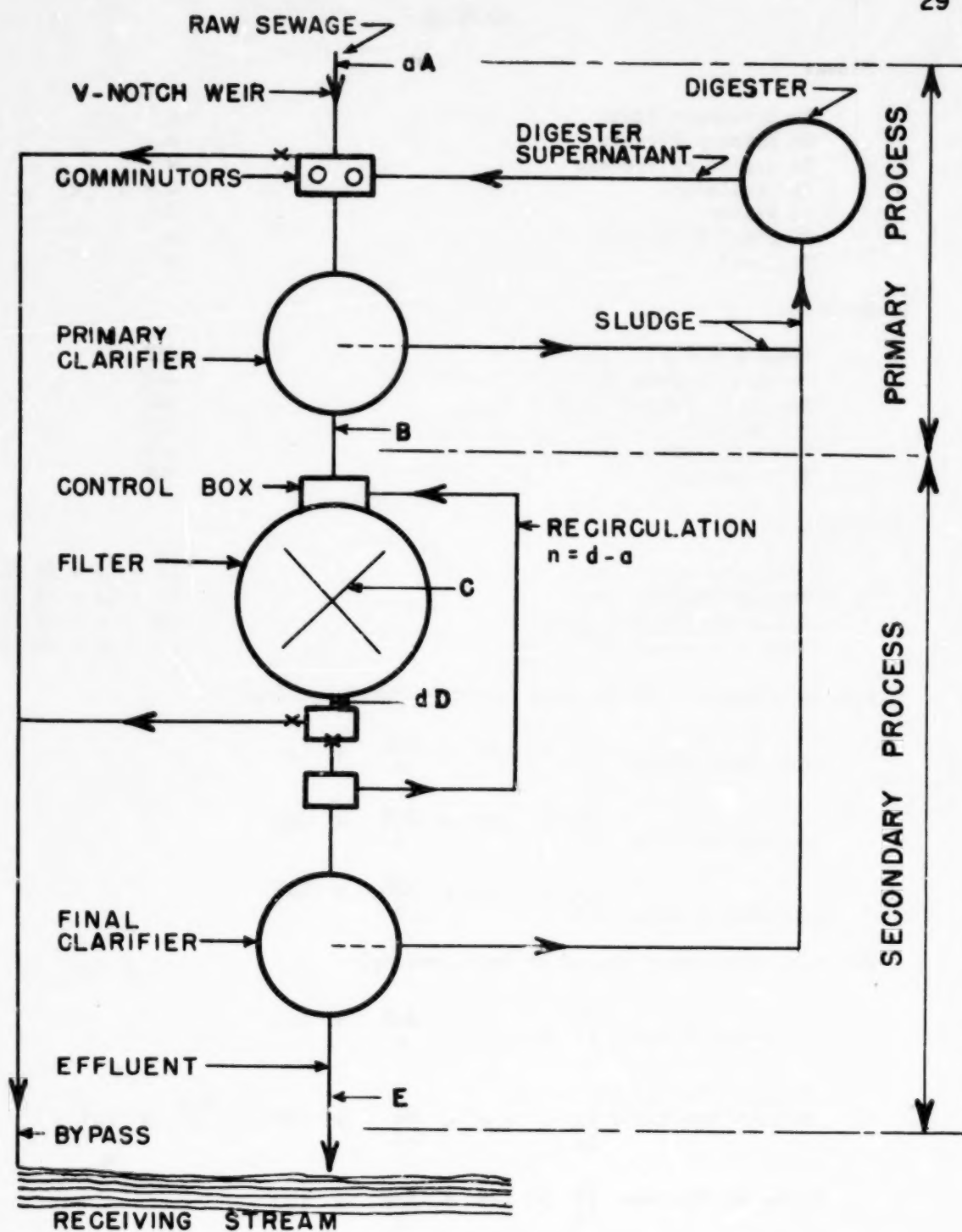
Sample Points

- A (Raw Sewage)
- B (Settled Sewage)
- C (Filter Influent)
- D (Filter Effluent)
- E (Final Effluent)

NOMENCLATURE

A, B, C, D, E	Concentrations in p.p.m.
a, d, n	Flows in M.G.D.
L, R	Pollutant material in pounds per day
K	A constant = $8.34 = \frac{\text{lbs./day}}{\text{M.G.D.} \times \text{p.p.m.}}$

NOTE: Secondary unit and filter loadings are reported as M.G.A.D. and lbs. per cu. yd. based on area and volume of filter stone.



SEWAGE TREATMENT PLANT
FLOW DIAGRAM
NEWBERRY, S. C.

FORMULAS

Flows:

To Treatment Plant	a
To Primary Process	a
To Secondary Process	a
Recirculation	$n = d - a$
To Filter	d
To Final Clarifier	a
Effluent	a

Loadings:

Treatment Plant (Lt)	aAK
Primary Process (Lp)	aAK
Secondary Process (Ls)	aBK
Filter (Lf)	dCK
Final Clarifier (Lc)	aDK
Effluent (Le)	aEK

Removals

Treatment Plant (Rt)	$Lt - Le = aK (A-E)$
Primary Process (Rp)	$Lt - Ls = aK (A-B)$
Secondary Process (Rs)	$Ls - Le = aK (B-E)$
Final Clarifier (Rc)	$Lc - Le = aK (D-E)$

Per cent Removals (Efficiency based on Plant Loading)

$$\text{Treatment Plant } \frac{Rt}{Lt} \times 100 = \frac{A-E}{A} \times 100$$

$$\text{Primary Process } \frac{Rp}{Lt} \times 100 = \frac{A-B}{A} \times 100$$

$$\text{Secondary Process } \frac{Rs}{Lt} \times 100 = \frac{B-E}{A} \times 100$$

Per cent Efficiency (Based on Unit Loading)

$$\text{Treatment Plant } \frac{Rt}{Lt} \times 100 = \frac{A-E}{A} \times 100$$

$$\text{Primary Process or Primary Clarifier } \frac{Rp}{Lp} \times 100 = \frac{Rp}{Lt} \times 100 = \frac{A-B}{A} \times 100$$

$$\text{Secondary Process } \frac{Rs}{Ls} \times 100 = \frac{B-E}{B} \times 100$$

$$\text{Final Clarifier } \frac{Rc}{Lc} \times 100 = \frac{D-E}{D} \times 100$$

$$\text{Filter } \frac{Rf}{Lf} \times 100 = \frac{C-D}{C} \times 100$$